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Redistributive Tax Policy at the Zero Bound

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Abstract

Generating consumer price inflation with an increasing path of consumption taxes when the nominal interest rate zero lower bound is binding and monetary policy becomes ineffective, as proposed by Correia et al. [1], may not neutralize a liquidity trap when liquidity is constrained. Instead, this paper shows that a redistributive tax policy may counteract a zero bound recession in liquidity constrained economies with no need to increase public spending and debt, with a fiscal prescription curiously opposite to the one proposed by Correia et al. [1].

JEL classification: E21; E24; E31; E40; E43; E52; E62

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1 Introduction

Short term monetary policy may not counteract a recession when inflation is low and the zero bound of nominal interest rates prevents real rates to achieve a negative *natural rate of interest*¹ and ensure full-employment. Standard fiscal policy prescriptions to circumvent a liquidity trap are usually based on increasing public spending to stimulate demand².

Recently, however, Correia et al. [1] proposed an alternative approach to neutralize a zero bound recession based on distortionary taxes, with *"no need to use inefficient policies such as wasteful public spending or future commitments to low interest rates"*. Their fiscal prescription consists of generating inflation in consumer prices, the ones that matter for intertemporal decisions, with an increasing path of consumption taxes to achieve negative real rates at the zero bound. Simultaneously they reduce labor taxes such that producer price inflation remains equal to zero. Their results hold in a standard single agent New Keynesian framework where recessions are by construction temporary.

But liquidity traps may last many years, like the one in Japan described by Krugman et al. [10]. Causes for long duration zero bound recessions have been described in recent literature and are commonly explained by the declining trend of the natural rate of interest, which eventually becomes negative and unreachable due to the zero bound of nominal interest rates. Causes can range from population aging as described by Eggertsson et al. [2], increasing inequality, or credit constraints as modeled by Eggertsson and Mehrotra [5].

Sustaining an increasing path of consumption taxes for a long period of time may not be a viable fiscal policy option, in addition to the fact that increasing consumption taxes would negatively affect consumption of households if they are constrained, for example by borrowing limits, if they are recipients of a minimum wage

¹The natural rate of interest has been defined in the literature as the equilibrium full-employment real interest rate.

²Besides other non-fiscal approaches, namely the one proposed by Eggertsson and Woodford [6] where the central bank commits to keep interest rates at a lower level even after a recession resulting from a liquidity trap is over.

or a retirement pension.

Moreover, we show that decreasing labor income taxes as proposed by Correia et al. [1] (as a way to offset consumption tax reductions and to keep public debt constant) could expand savings while not affecting loan demand in credit constrained economies. This could drag further down the natural rate of interest below an attainable level, and worsen a zero bound recession.

If the fiscal prescription proposed by Correia et al. [1] may not be effective to circumvent a long duration liquidity trap, we alternatively propose a redistributive tax policy, curiously opposite to their solution in the way taxes change. We show that such a policy prescription may be used to sustain, or bring back the real rate to a viable full-employment level, and thus prevent, or counteract, a liquidity trap, while keeping public spending and debt unchanged.

The intuition for why this policy is effective to prevent or counteract a zero bound recession in a constrained economy is simple. Suppose that the natural rate of interest ought to be persistently negative and the nominal rate is at the zero bound. Since negative real rates cannot be attained if inflation is low, then either the natural rate of interest is increased back to a viable full-employment level, or inflation must be generated to allow negative real rates so that a negative natural rate of interest may be attained.

Increasing the real rate is possible if there is a way to contract aggregate savings in the economy while keeping aggregate borrowing unchanged. A contraction of aggregate savings can be achieved via a reduction of households' net income with an increase of labor income taxes.

Aggregate borrowing may not be affected: If borrowers are constrained by binding borrowing limits then private borrowing might not be directly affected by an increase of labor income taxes, specially if income taxes only increase for higher income and unconstrained agents. Moreover, public borrowing may also not be affected if a sufficient reduction of consumption taxes offsets the increase of income taxes.

It turns out that savings may be affected by intertemporal decisions via consumer

prices, which are gross of consumption taxes. But consumption taxes would not affect intertemporal decisions if they are not expected to change in the future, independently of their current level. Then, consumption tax reduction in current period does not affect savings via the intertemporal decision if no more changes are expected in the future.

Moreover a consumption tax reduction increases consumption of constrained agents, and can offset the negative impact of increasing real rates on aggregate demand. This redistributive tax policy reduces net income of workers by increasing taxes on wages, to the benefit of constrained agents who can increase consumption because of lower consumption taxes.

With respect to recent economic literature this paper proposes a fiscal prescription to counteract zero bound recessions when liquidity constraints are present, with no need to increase public spending and debt (as proposed by Eggertsson and Mehrotra [5] recent work). We outline the limitations of the solution proposed by Correia et al. [1] to circumvent a liquidity trap of long duration in liquidity constrained economies, and we provide an effective alternative solution based on fiscal redistribution.

Going forward, section 2 describes a three overlapping generations model, based on the work of Eggertsson and Mehrotra [5], where in the first period households are young and cannot borrow above a binding limit. In the second period households are middle age, receive income from wages and firms profits, and save for retirement by lending to the young. They don't accept nominal wage reductions. In the third period the old dissave to consume. Firms hire labor, pay wages and distribute profits. Consumers pay consumption taxes, and labor taxes are payed by workers and firms. In this economy the natural rate of interest can be permanently negative, and a recession can last a long period of time.

Section 3 compares two alternative tax policies to prevent a zero bound recession. We show that in our constrained economy, the *Unconventional Tax Policy at the Zero Bound* proposed by Correia et al. [1] is ineffective to prevent a zero bound recession of long duration. We alternatively present our *redistributive tax policy* based on an opposite fiscal prescription, and describe how it can increase

the natural rate of interest to a viable level while sustaining aggregate demand at full-employment.

Section 4 shows that our redistributive tax policy may also be used to achieve a transition from a persistent recession to a stable full-employment equilibrium. Additionally we also describe an alternative transition mechanism to full-employment that allows negative real rates by generating inflation in the supply side of the economy with increasing labor taxes on firms. This alternative approach that causes a contraction of aggregate supply is inspired in the *Paradox of Toil* described in Eggertsson [3].

2 A Simple OLG Model with Distortionary Taxes

This section describes a simple overlapping generations economy where households pay taxes on income and on consumption, and are credit constrained in the beginning of their lives as proposed by Eggertsson and Mehrotra [5]. Generations can borrow and lend to one another and to the Government to smooth consumption over time, and nominal wages cannot be adjusted downwards. Firms pay taxes on hired labor. In this model real rates can be persistently negative, and steady state recessions are possible.

(i) Households

Households go through three stages of life. During the first period of their lives they are young and need to borrow to consume, subject to a credit constraint. During the second and middle-age period they work to consume and to save for retirement, and also pay their debts from previous period. Household retire when they are old in the third period, and use their savings to consume. Consumption is taxed. Households maximize an objective function of consumption given by:

$$\max_{C_t^y, C_{t+1}^m, C_{t+2}^o} E_t \{ U(C_t^y) + \beta U(C_{t+1}^m) + \beta^2 U(C_{t+2}^o) \} \quad (1)$$

where C_t^y , C_{t+1}^m , and C_{t+2}^o are respectively the consumption of an household when

young, middle age, and old. $U(C)$ is a constant elasticity of inter-temporal substitution utility function expressed by $U(C) = \frac{C^{1-\sigma}}{1-\sigma}$, where $1/\sigma$ is the elasticity of intertemporal substitution.

Households borrow and lend to one another via one period risk-free bonds B_t^i at a nominal interest rate i_t . They face the following budget constraints in each period of their lives:

$$P_t(1 + \tau_t^c)C_t^y = P_t B_t^y \quad (2)$$

$$P_{t+1}(1 + \tau_{t+1}^c)C_{t+1}^m = Z_{t+1} + W_{t+1}L_{t+1}(1 - \tau_{t+1}^l) - (1 + i_t)P_t B_t^y + P_{t+1} B_{t+1}^m \quad (3)$$

$$P_{t+2}(1 + \tau_{t+2}^c)C_{t+2}^o = -(1 + i_{t+1})P_{t+1} B_{t+1}^m \quad (4)$$

$$(1 + i_t)P_t B_t^y \leq P_{t+1} D_t, \text{ an exogenous borrowing limit.} \quad (5)$$

P_t is the aggregate price level at time t , and consumption is taxed at a rate τ_t^c . It is assumed that the young don't work, and thus borrow $P_t B_t^y$ from the middle-age to consume³.

Only the middle generation earns income in the form of firms profits $Z_t = P_t z_t$ and net wages $(1 - \tau_t^l)L_t W_t$, where nominal wages $W_t = P_t w_t$ are taxed at a rate τ_t^l . L_t is labor endowment supplied inelastically by the middle generation at \bar{L} , although firms may hire only part of it so that $L_t \leq \bar{L}$. The middle-age use their income to consume, to save $-P_t B_t^m$ for retirement by lending to the young and to the Government, and to pay back their loans from the previous period.

The old don't work. They consume by using all their savings from previous period gross of interests i_t .

Assuming perfect foresight the real interest rate is given by a Fisher equation:

$$1 + r_t = (1 + i_t) \frac{P_t}{P_{t+1}} \Leftrightarrow 1 + i_t = (1 + r_t) \Pi_t \quad (6)$$

where $\Pi_t = \frac{P_{t+1}}{P_t}$ is the growth rate of price level.

³This assumption is a simplification of a young generation supplying low productivity labor and subject to a binding minimum wage. It does not change our findings.

Real borrowing is constrained by an exogenous limit D_t (as in Eggertsson and Krugman [4]), which we assume is binding for the young, so that using expressions (5) and (6) we have:

$$B_t^y = \frac{D_t}{1 + r_t} \quad (7)$$

Since the young borrow up to their limit to satisfy their consumption needs, a reduction of consumption taxes would increase their level of consumption⁴, so that by combining (2) and (7) consumption of the young is expressed by:

$$C_t^y = \frac{B_t^y}{1 + \tau_t^c} = \left(\frac{1}{1 + \tau_t^c} \right) \frac{D_t}{1 + r_t} \quad (8)$$

In turn, the old use their savings from previous period to consume. Then a reduction of consumption taxes has also a positive effect on their consumption level so that:

$$C_t^o = - \left(\frac{1}{1 + \tau_t^c} \right) (1 + r_{t-1}) B_{t-1}^m \quad (9)$$

Consequently an increase of consumption taxes as proposed by Correia et al. [1] would lead, in this economy, to a contraction of consumption of young and old generations⁵.

Regarding the middle-age, their consumption is determined by the intertemporal condition given by:

$$1 + i_t = \frac{1}{\beta} \mathbb{E}_t \left[\frac{(1 + \tau_{t+1}^c) P_{t+1}}{(1 + \tau_t^c) P_t} \right] \frac{U_c(C_t^m)}{U_c(C_{t+1}^o)} \Leftrightarrow 1 + r_t = \frac{1}{\beta} \mathbb{E}_t \frac{1 + \tau_{t+1}^c}{1 + \tau_t^c} \frac{U_c(C_t^m)}{U_c(C_{t+1}^o)} \quad (10)$$

This Euler equation is similar to the one derived by Correia et al. [1]. In their paper they propose an increasing path of consumption taxes in order to raise inflation during a liquidity trap, when the nominal interest rate zero bound is binding and a negative real rate is required to sustain full employment. But in our constrained economy this same prescription may lead to very different, and even opposite results, as we later explain in detail. First, because an increasing path of taxes can

⁴Our results would not change if the young were recipients of a binding minimum wage.

⁵For the same interest rate level.

only be a temporary solution, unsuited for a persistent problem like a liquidity trap of long duration. Second, because an increase in consumption taxes has the undesirable outcome of reducing consumption of constrained agents, if credit constrained, receiving minimum wage, pension income, or dissaving to consume. Third, because an increase in consumption taxes would require a reduction of labor taxes to keep public debt constant. A reduction of labor income taxes would in turn expand savings which would undesirably drag further down the natural rate of interest to even lower unattainable levels.

(ii) *Firms*

We assume perfect competition on the firm side. Firms hire labor L_t to maximize profits Z_t on a period by period basis, and pay taxes on labor at a rate τ_t^w . The firm problem is given by⁶:

$$Z_t = \max_{L_t} P_t Y_t - W_t L_t (1 + \tau_t^w) \quad (11)$$

$$\text{s.t. } Y_t = L_t^\alpha \quad (12)$$

Nominal wage is given by firms' labor demand condition, so that:

$$W_t = \frac{\alpha}{1 + \tau_t^w} \frac{P_t Y_t}{L_t} = \frac{\alpha}{1 + \tau_t^w} P_t L_t^{\alpha-1} \quad (13)$$

It is assumed that households will not work for a wage lower than the nominal wage of previous period. The nominal wage may then be greater than the flexible labor full-employment nominal wage W_t^{flex} :

$$W_t = \max\{W_{t-1}, W_t^{flex}\}, \text{ where } W_t^{flex} = \frac{\alpha}{1 + \tau_t^w} P_t \bar{L}^{\alpha-1} \quad (14)$$

When firms are prevented to adjust the nominal wage (13) downwards, namely in response to a decline of aggregate price level or an increase of labor taxes on firms, labor market may clear at a level lower than full-employment \bar{L} . From equation

⁶In appendix we describe a version of the model with capital.

(14) labor demand can be expressed by:

$$L_t = \min \left\{ \bar{L}, \left(\Pi_t \frac{1 + \tau_{t-1}^w}{1 + \tau_t^w} \right)^{\frac{1}{1-\alpha}} L_{t-1} \right\} \leq \bar{L} \quad (15)$$

If labor tax on firms is constant ($\tau_t^l = \tau_{t-1}^l$) and inflation is negative, then wages cannot adjust downwards, labor demand is under full-employment, and the economy is in a recession:

$$\Pi_t < 1 \xRightarrow{\tau_t^w = \tau_{t-1}^w} L_t = L_{t-1} \Pi_t^{\frac{1}{1-\alpha}} < \bar{L} \quad (16)$$

(iii) Government

In this economy, the Government borrows from households and collects taxes to spend in public services and to pay debt and interests from previous period, according to the budget constraint:

$$B_t^g = G_t - T_t + \frac{1 + r_{t-1}}{1 + g_{t-1}} B_{t-1}^g, \text{ where } T_t = \tau_t^c C_t + (\tau_t^l + \tau_t^w) w_t L_t \quad (17)$$

B_t^g is Government debt per middle age household, N_t is the size of the young generation at time t , and $1 + g_t = N_t / N_{t-1}$ is the gross growth rate of the young.

(iv) Monetary policy

Suppose that the central bank sets the nominal interest rate according to a standard Taylor rule in order to stabilize inflation around a target Π^* :

$$1 + i_t = \max \left\{ 1, (1 + i^*) \left(\frac{\Pi_t}{\Pi^*} \right)^{\phi_\pi} \right\} \Rightarrow i_t \geq 0 \quad (18)$$

i^* and Π^* are respectively the Central Bank targets for interest rate and inflation, and $\phi_\pi > 1$ is the Taylor parameter. The nominal interest rate zero bound is binding when inflation is lower than a threshold level $\Pi^{kink} = \frac{\Pi^*}{(1+i^*)^{\frac{1}{\phi_\pi}}} \leq \Pi^*$, so that a

corresponding lower bound for the real rate is given by:

$$1 + r_t = \frac{1 + i_t}{\Pi_t} \geq \frac{(1 + i^*)^{\frac{1}{\phi\pi}}}{\Pi^*} = 1 + r^{kink} \quad (19)$$

Consequently, a necessary condition (although not sufficient) for full-employment requires that the *natural rate of interest* r_t^n is greater than the real rate lower limit r^{kink} .

(v) *Equilibrium*

Loan market is in equilibrium when savings of the middle age $-N_{t-1}B_t^m$ equals borrowing of the young and the Government $N_tB_t^y + N_{t-1}B_t^g$ so that:

$$(1 + g_t)B_t^y + B_t^g = -B_t^m \quad (20)$$

An equilibrium is defined as a set of processes $\{C_t^y, C_t^m, C_t^o, B_t^y, B_t^m, L_t, Y_t, Z_t\}$ and prices $\{P_t, W_t, r_t, i_t\}$ solving (2), (6), (8), (9), (10), (11), (12), (13), (17), (18) (20).

In this model a persistent recession is possible. A necessary condition for a steady state recession is a negative natural rate of interest, $r_t^n < 0$. But, if $r_t^n > r^{kink}$ then full-employment may also be a viable equilibrium. In the particular case where $r^{kink} < r_t^n < 0$ the model may have two stable steady state solutions: a recession, and full employment⁷ as shown in Figure 2.

Let's then take a closer look at the determination of the real rate from loan market equilibrium, when loan demand $L^d(r_t)$ equals loan supply $L^s(r_t)$, also given by expression (20).

Loan demand can be expressed in terms of the borrowing limit D_t substituting out for the borrowing of the young (8), so that:

$$L_t^d = B_t^{yg} = \frac{N_t}{N_{t-1}}B_t^y + B_t^g = \frac{1 + g_t}{1 + r_t}D_t + B_t^g \quad (21)$$

Assuming that the government keeps the budget balanced so that public debt per

⁷The properties and determinacy of this model are described in detail by Eggertsson and Mehrotra [5].

middle age household remains constant, $B_t^g = \bar{B}^g$, then loan demand L_t^d is a decreasing function of the real rate r_t . Observe that a contraction of loan demand may be caused by public debt deleveraging \bar{B}^g , or by the worsening of credit conditions D_t on households.

Loan supply, in turn, is derived by combining the intertemporal condition (10), consumption of the old (9), of the young (8), and of the middle age (3):

$$L_t^s = -B_t^m = \frac{(1 - \alpha \tau_t^{lw})Y_t - D_{t-1}}{1 + \frac{1}{\beta^{\frac{1}{\sigma}} \left[(1 + r_t) \frac{1 + \tau_t^c}{1 + \tau_{t+1}^c} \right]^{1 - \frac{1}{\sigma}}}}, \text{ where } \tau_t^{lw} = \frac{\tau_t^l + \tau_t^w}{1 + \tau_t^w} \quad (22)$$

Observe that consumption taxes affect gross consumer prices, so that savings decision is affected by expected changes of consumption taxes via the intertemporal condition (10).

However, a permanent change of consumption taxes in period t remaining constant thereafter, so that $\tau_{t+1}^c = \tau_t^c \neq \tau_{t-1}^c$, does not directly affect the savings decision of middle age. First, because middle age have to pay back what they borrowed when young, which does not depend on current taxes. Second, because the amount the middle age save is determined by the amount the young can borrow which does not depend on the taxes the young pay: if consumption taxes increase the young reduce consumption to pay higher consumption taxes, and vice-versa, but they don't change the amount they borrow. Moreover, if consumption taxes are not expected to change in the future relative to their current level then they don't affect the intertemporal condition (10), and thus do not affect savings as well as the real rate.

The level of labor taxes, however, directly affects loan supply. An increase of labor taxes reduces net income of the middle age, as well as their consumption and savings.

Distortionary taxes can then be used to change the real rate via their impact on savings⁸, in particular to counteract any economic force dragging it down eventually below a full-employment threshold, like population aging, increasing inequality, or debt deleveraging. In particular, the real rate can be increased with a tax prescription

⁸taxes do not affect borrowing in this economy, assuming public debt constant.

causing a contraction of loan supply⁹. We now describe two alternative tax policies, and their impact on the real interest rate.

3 Counteracting a negative shock on the natural rate of interest

The objective of this paper is not to show that the natural rate of interest can become persistently negative due to population aging (as described by Eggertsson, Lancastre and Summers (2019)), or due to a deleveraging shock (see Eggertsson and Mehrotra [5]), or that a proper tax policy mix can counteract a temporary liquidity trap while keeping public spending and debt constant (see Correia et al. [1]).

A key contribution of this paper, however, is to present a fiscal policy prescription able to prevent and counteract a liquidity trap of very long duration with no need to increase public spending and debt, when agents are constrained in their ability to consume. The motivation for the paper was the fact that the fiscal policy prescription proposed by Correia and al (2014) to counteract a temporary liquidity trap (based on an increasing path of consumption taxes while keeping the budget balanced by increasing taxes on labor) may not be effective in a constrained economy, and certainly not effective when the natural rate of interest becomes persistently lower than the real rate lower limit r^{kink} .

(i) Generating consumer price inflation with consumption tax

In their recent paper "*Unconventional Fiscal Policy at the Zero Bound*", Correia et al. [1] present a fiscal prescription that neutralizes the negative effects of the zero bound in a standard single agent New Keynesian model where a liquidity trap is temporary by construction, with no need to increase public spending and debt. They propose to generate consumer price inflation with an increasing path of consumption taxes so that the intertemporal condition (10) is satisfied while real rates ought to be negative. At the same time they keep producer price inflation at zero by

⁹A contraction of loan supply has a positive effect on the real rate if the ratio of public to total debt B^g/L^d is smaller than the elasticity of intertemporal substitution $1/\sigma$. This is a reasonable condition since standard estimations of EIS are usually around and above 0.5 (see Havranek et al. [8]), and the ratio of government debt B^g to total debt is usually lower in developed economies. Going forward we assume this condition holds

decreasing labor taxes.

In our model a similar type of consumer price inflation could be generated with a decision to increase consumption taxes next period. This would increase consumer prices gross of taxes, the ones that matter for intertemporal decisions, giving the middle age an incentive to replace consumption when old with consumption in current period. This intertemporal substitution effect would have a partial negative impact on middle age savings. But the decision to increase consumption taxes next period also reduces the present value of middle age income net of taxes. A negative income effect on the middle age would reduce current consumption and in turn increase current savings.

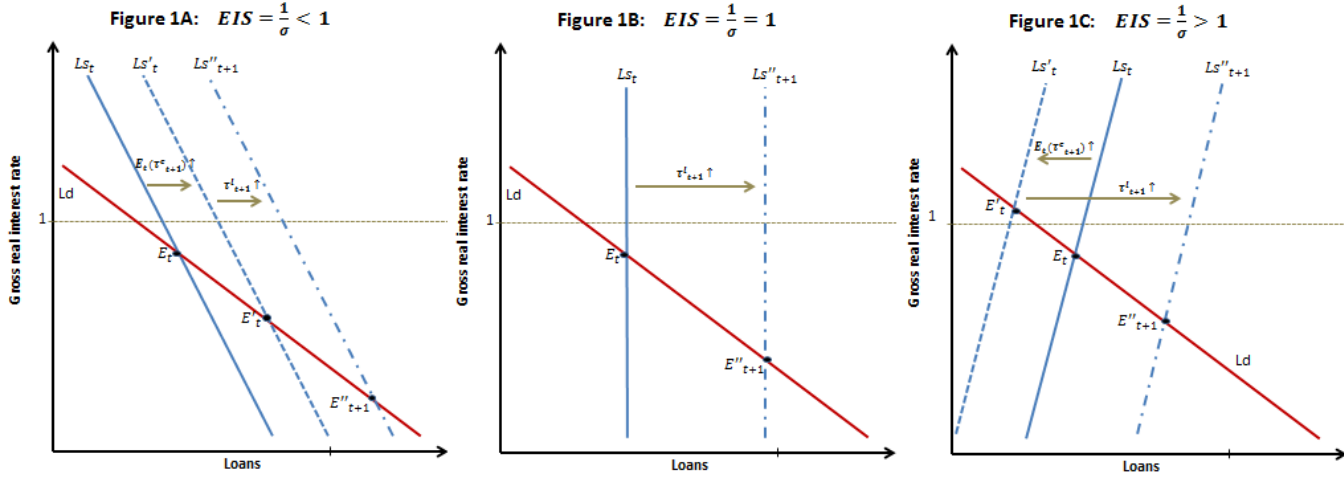
If the elasticity of intertemporal substitution (EIS) is smaller than 1 in this model, then the income effect would prevail over the substitution effect causing a net reduction of consumption of middle age. Then savings would increase, and the real rate would fall in current period. This effect is opposite to the one described by Correia et al. [1].

Otherwise, if $EIS > 1$ then an increasing path of consumption taxes causes a net contraction of loan supply and increases real rate in current period, as described in Correia et al. [1].

Assuming that consumption taxes are kept constant after next period ($\tau_{t+2}^c = \tau_{t+1}^c$), then during next period loan supply would assume its initial form before the decision to increase τ_{t+1}^c . This would reduce public debt at time $t + 1$ if labor taxes would be kept unchanged. A decision to increase τ_{t+1}^c would then cause a contraction of loan demand and a decrease of the interest rate next period relative to its initial level, which would be an undesirable outcome. Otherwise, to keep public debt constant next period ($B_{t+1}^g = \bar{B}^g$) labor taxes τ_{t+1}^l should be reduced. This would expand loan supply and thus would also reduce the real rate r_{t+1} next period, again an undesirable outcome.

This economy would then always end-up with a lower real rate relative to its initial level, following a decision to increase consumption taxes next period, independently of the elasticity of intertemporal substitution, as shown in Figure 1.

Figure 1: Equilibrium in the loan market



The solution proposed by Correia et al. [1] to counteract a liquidity trap can then not be generalized. Their fiscal prescription would not be effective in preventing the natural rate of interest from falling in a credit constrained economy, such as the one we describe in this paper, even if a negative shock on real rates is temporary. Using their policy, the real rate after the shock would be lower than its pre-shock level.

Moreover, if the negative shock on the natural rate of interest is persistent, any policy based on an increasing or decreasing path of taxes may be unsustainable given the longer duration of the shock.

Additionally, a decision to increase consumption taxes in the future would be difficult to implement. It would penalize consumption of the most constrained: the young earning a minimum wage and credit constrained, as well as the retired earning a fixed retirement income or dissaving to consume. In addition to the fact that a reduction of labor taxes would only favor the middle age. In this economy, the policy proposed by Correia et al. [1] would increase inequality in future consumption between constrained and unconstrained agents.

(ii) *Taxing the unconstrained, and relieving the constrained*

We now analyze a fiscal policy prescription to prevent a liquidity trap based on increasing labor taxes on working middle age, and redistribute the tax proceeds among all households via a consumption tax reduction.

If the full-employment real rate r^n ought to be dragged down below an achievable lower limit r^{kink} , for example due to aging population or a deleveraging shock, then a sufficient contraction of loan supply could prevent the decline of r^n , and eventually prevent a zero bound recession.

A contraction of loan supply can be achieved by increasing labor taxes. This would reduce net income of the middle age, with a negative impact on their savings (see loan supply expression (22)).

In turn, in order to keep public debt \bar{B}^g constant consumption taxes would have to be reduced in current period t , remaining at the same level thereafter.

As previously observed, consumption taxes only affect loan supply via the intertemporal condition, if $\tau_{t+1}^c \neq \tau_t^c$. By discarding an increasing (or decreasing) path of consumption taxes from the set of fiscal tools to prevent a liquidity trap, the intertemporal condition becomes independent of consumption taxes, and equilibrium in the loan market given by (20) only depends on taxes during current period. Then, without loss of generality, a log utility of consumption ($EIS = 1/\sigma = 1$) is assumed going forward so that previous algebraic expressions can be simplified, and the natural rate of interest gets a closed-form expression given by:

$$1 + r_t^n = \frac{(1 + g_t)D_t}{\frac{\beta}{1+\beta} \left[(1 - \alpha \tau_t^{lw}) Y_t^f - D_{t-1} \right] - B_t^g} \quad (23)$$

We observe directly from this expression that the natural rate of interest can be negatively affected by (i) population aging due to a decline of the population growth g_t rate (see Eggertsson, Lancastre, and Summers (2019)), by a deleveraging shock due to (ii) a reduction of public debt B_t^g , or (iii) an increase of credit constraints on households D_t (see Eggertsson and Mehrotra (2014)).

Negative effects of those shocks on r^n can be counteracted by increasing labor taxes given by τ_t^{lw} . Such changes of labor taxes to sustain full-employment real rate

at a pre-shock level can be expressed as follows:

$$\Delta \tau^{lw} \geq -\frac{1}{\alpha} \left(\frac{1+\beta}{\beta} \right) \frac{1}{1+r_t^n} \frac{D_t}{Y^f} \Delta g_t \quad (24)$$

$$\Delta \tau_t^{lw} \geq -\frac{1}{\alpha} \left(\frac{1+\beta}{\beta} \right) \Delta \left(\frac{B_t^g}{Y^f} \right) \quad (25)$$

$$\Delta \tau^{lw} \geq -\frac{1}{\alpha} \left(\frac{1+\beta}{\beta} \right) \frac{1+g_t}{1+r_t^n} \Delta \left(\frac{D_t}{Y^f} \right) \quad (26)$$

But an increase of labor taxes would have a negative impact on consumption of middle age by reducing their net income, so that:

$$C_t^m = \left(\frac{1}{1+\tau_t^c} \right) \left(\frac{1}{1+\beta} \right) \left[(1-\alpha \tau_t^{lw}) Y_t - D_{t-1} \right] \quad (27)$$

Sustaining full-employment ($Y_t = Y^f$), as well as the level of aggregate consumption, requires a reduction of consumption taxes τ_t^c to counteract the negative effect of an increase of labor taxes τ_t^{lw} on consumption of middle age. A consumption tax reduction also increases consumption of young and old, respectively given by expressions (8) and (9).

The reduction of consumption tax required to sustain consumption at its full-employment level is also the same consumption tax reduction that keeps constant total taxes and public debt. The change in consumption taxes with respect to the change in labor taxes can be derived by the budget constraint (17), so that:

$$\partial \tau_t^c = -\alpha \left(\frac{1+\tau_t^c}{1-\alpha \tau_t^{lw}} \right) \partial \tau_t^{lw} \quad (28)$$

Aggregate consumption C_t can in turn be expressed with respect to consumption tax τ_t^c by combining the budget constraints of the young (8) and the old (9), the Euler equation (10), loan market equilibrium (21), and the budget constraint (17), so that:

$$N_{t-1} C_t = N_t C_t^y + N_{t-1} C_t^m + N_{t-2} C_t^o \Leftrightarrow C_t = (1+g_t) C_t^y + C_t^m + \frac{C_t^o}{1+g_{t-1}} \Leftrightarrow \quad (29)$$

$$C_t = \frac{1}{1+\tau_t^c} \left\{ \left[\left(\frac{1+\beta}{\beta} \right) \frac{1+g_t}{1+r_t} D_t + D_{t-1} \right] + \left[\frac{B_t^g}{\beta} + \frac{1+r_{t-1}}{1+g_{t-1}} B_{t-1}^g \right] \right\} \quad (30)$$

Unsurprisingly, aggregate consumption is a negative function of the consumption tax in this economy, and aggregate demand is given by

$$Y_t^d = C_t + G \quad (31)$$

We observe from consumption and aggregate demand expressions that the same shocks that can drag down the natural rate of interest would also cause a contraction of aggregate demand.

The remedy to sustain the natural rate of interest at a full-employment level (an increase of labor taxes) is consistent with the remedy to prevent a contraction of aggregate demand (a reduction of consumption taxes), while keeping public spending and debt constant.

This fiscal policy has an intergenerational redistributive effect, by increasing consumption of the young and the old, and by reducing consumption of the unconstrained middle age.

Finally, and curiously, this tax prescription to counteract a liquidity trap is opposite to the *Unconventional Fiscal Policy at the Zero Bound* proposed by Correia et al. [1].

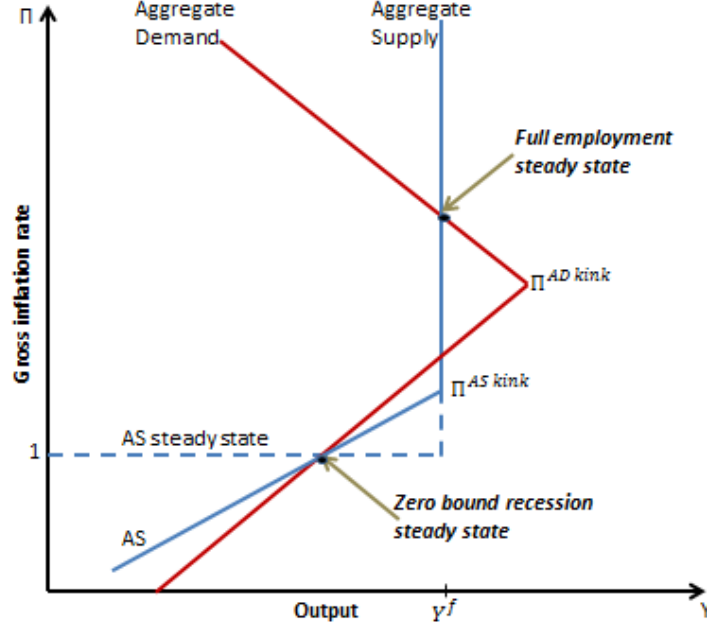
4 Transition from a zero bound recession to full-employment

Although the redistributive tax policy previously described can be effective at sustaining the natural rate of interest above its full-employment threshold, it may not be sufficient to prevent a temporary, or even a persistent recession.

In fact this economy can have two stable steady state solutions as illustrated in Figure 2 depicting aggregate supply and aggregate demand: a full-employment steady state and a persistent recession. This means that the economy may find itself in a persistent recession even if the natural rate of interest is reachable.

To analyze a recession in our economy we need to take a look at the role of inflation on aggregate supply and aggregate demand.

Figure 2: Aggregate demand and aggregate supply curves



Aggregate Supply AS:

We have previously observed from expression(15) that labor demand depends on the level of inflation because nominal wages cannot adjust downwards. In particular, firms may only ensure full-employment if inflation is greater than a lower threshold given by:

$$\Pi_t \geq \left(\frac{\bar{L}}{L_{t-1}} \right) \left(\frac{1 + \tau_t^w}{1 + \tau_{t-1}^w} \right)^{\frac{1}{1-\alpha}} \equiv \Pi_{AS}^{kink} \quad (32)$$

Aggregate supply can be derived from labor demand expression(15):

$$Y_t^s = \min \left\{ Y^f, Y_{t-1}^s \left(\Pi_t \frac{1 + \tau_{t-1}^w}{1 + \tau_t^w} \right)^{\frac{\alpha}{1-\alpha}} \right\} \quad (33)$$

When inflation is greater than Π_{AS}^{kink} AS curve is represented in figure 2 by a vertical line representing full-employment. When inflation is smaller than Π_{AS}^{kink} the aggre-

gate supply curve is upward sloping representing increasing function of inflation. Observe that during a recession an increase of labor taxes on firms τ_t^w contracts aggregate supply.

In steady state it is assumed that taxes are constant, and aggregate supply is expressed by:

$$Y^s = \min \left\{ Y^f, Y^s \Pi \right\} \quad (34)$$

During a steady state recession inflation is equal to zero. In steady state, the lower segment of the aggregate supply curve in Figure 2 is given by an horizontal line at $\Pi = 1$.

Aggregate Demand AD:

In turn, AD as a function of inflation is derived by replacing the real rate r_t expressed in terms of inflation in aggregate consumption (29), depending on whether the nominal interest rate is equal or greater than zero ¹⁰.

If inflation is higher than the threshold Π_{AD}^{kink} then the nominal interest rate is positive and increases with inflation at a rate greater than one¹¹. Then real rate increases with inflation which in turn reduces output, which explains the downward slope of AD upper segment in Figure 2.

If inflation is lower than the threshold Π_{AD}^{kink} then the nominal interest rate is bounded at zero, and $1 + r_t = 1/\Pi_t$. In this case higher inflation decreases the real rate and increases output, which explains the upward slope of AD lower segment in Figure 2.

Going forward, and without loss of generality, we assume the budget is always balanced ($G_t = T_t$) and public debt $B_t^g = 0$. Aggregate demand can then be ex-

¹⁰From the nominal interest rate expression (18), at the zero lower bound $1 + r_t = \frac{1}{\Pi_t}$. Otherwise, if $i_t > 0$, then $1 + r_t = \frac{1}{\Pi_t} \left(\frac{\Pi_t}{\Pi_{kink}} \right)^{\phi_\pi}$.

¹¹Monetary policy according to Taylor rule(18)

pressed by:

$$i_t > 0; \Pi_t > \Pi^{kink}: Y_t^d = \frac{1}{1 + \tau_t^c} \left[\frac{(1 + \beta)(1 + g_t)D_t}{\beta} \frac{\Pi_{kink}^{\phi_\pi}}{\Pi_t^{\phi_\pi - 1}} + D_{t-1} \right] + G_t \quad (35)$$

$$i_t = 0; \Pi_t \leq \Pi^{kink}: Y_t^d = \frac{1}{1 + \tau_t^c} \left[\frac{(1 + \beta)(1 + g_t)D_t}{\beta} \Pi_t + D_{t-1} \right] + G_t \quad (36)$$

Steady state AD has the same expression and graphical representation, assuming constant binding borrowing limit $D_t = D_{t-1} = D$.

A steady state recession is represented in Figure 2 by the intersection of AS and AD lower segments¹². We now describe two possible transitions from a steady state zero bound recession to full-employment, assuming that a full-employment equilibrium is a viable solution of the model, ($0 > r_n \geq r_{kink}$).

(i) *Expanding aggregate demand by reducing consumption taxes*

Let's assume that the economy is in a persistent recession illustrated in Figure 2, as the real rate is higher than the natural rate of interest now expressed in terms of τ_t^c :

$$1 + r_t^n = \frac{1 + \beta}{\beta} \frac{(1 + g_t)D_t}{(Y^f - G_t)(1 + \tau_t^c) - D_{t-1}} \quad (37)$$

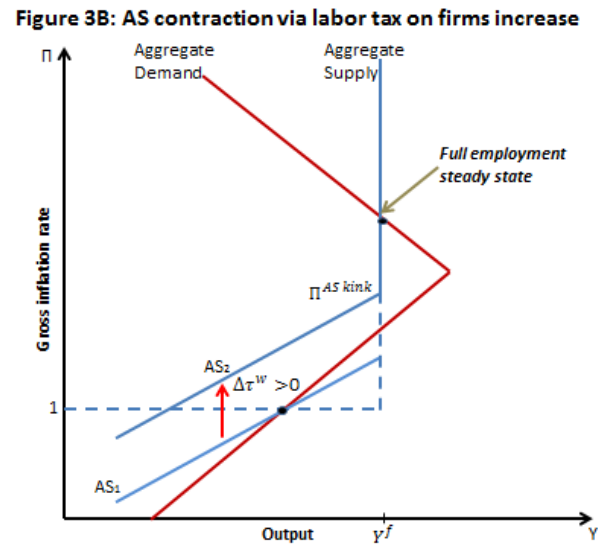
A consumption tax reduction expands aggregate demand in this credit constrained economy as explained previously. This expansion of demand generates inflation, in turn allowing firms to reduce real wages and hire more workers to increase production. In addition, higher inflation also reduces real rates at the zero bound, further expanding demand.

A persistent recession ($Y < Y^f$) could be overcome with a sufficient reduction of the consumption tax ($\Delta \tau^c < 0$) such that the natural rate of interest (given by expression (37)) becomes positive, and the recession is removed from the set of viable

¹²Note that all three segments representing short term AS, steady state AS, and AD, intersect at the same point. The properties of a recession in this model are described in detail by Eggertsson and Mehrotra [5]. In particular, (i) a steady state recession requires a negative natural rate of interest r^n . And (ii) a steady state recession is stable only if AD lower segment is steeper than AS lower segment.

$$\Delta \tau^c \leq (1 + \tau^c) \left(\frac{Y - Y^f}{Y^f - G} \right) < 0 \quad (38)$$

Figure 3: Counteracting a Zero Bound Recession



The decision to decrease consumption taxes during a recession may be difficult

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to implement by a Government prevented to increase public debt. Transition from a recession to full-employment can alternatively be achieved with a contraction of aggregate supply by increasing labor taxes on firms, with no change of consumption taxes.

In fact, if τ_t^w increases then firms will produce less at the same price level. To keep production constant firms need to increase their prices. In both cases, at the zero bound, inflation increases and the real rate decreases. A reduction of real rates will in turn increase demand.

Additionally, firms facing higher inflation also may get some room to reduce real wages and increase production.

The economy ends-up at a new equilibrium with higher output and inflation. If the supply contraction is sufficiently large then full-employment output Y^f may even be achieved.

But assuming taxes are constant in the long-run then a supply contraction due to a change in taxes can only be temporary. When labor tax on firms stabilizes after the adjustment such that $\tau_{t+1}^w = \tau_t^w > \tau_{t-1}^w$ aggregate supply expands back to its initial state in period $t + 1$.

Although the effects of an increase of labor tax on firms on aggregate supply may only be temporary, it generates inflation that may be sufficient to clear a recession from the set of viable equilibria at least for one period. This policy illustrated in Figure 3 could promote a transition to full-employment even if the natural rate of interest r_t^n stays negative, as long as $r_n > r_{kink}$.

Using aggregate supply expression (33) and assuming the economy is in a stable recession where $Y_t < 0$, $\pi_t = 0$ with $r_{kink} < r_n < 0$ and constant τ_t^c , an increase in labor taxes sufficient to remove during one period a recession from the set of viable equilibria, can be expressed by¹⁴:

$$\Delta \tau^w \geq (1 + \tau^w) \left[\frac{1}{1 + r^n} \left(\frac{Y}{Y^f} \right)^{\frac{1-\alpha}{\alpha}} - 1 \right] \quad (39)$$

¹⁴We are assuming that the consumption tax and the natural rate of interest remain constant.

If the government decides not to change consumption taxes then labor taxes on the middle age would have to be reduced in order to keep a balanced budget and public debt equal to zero. In this case a transition to full-employment would be achieved with a reduction of labor taxes on firms τ_w and an increase of labor taxes on households τ^l .

An alternative, and perhaps more implementable policy would be to combine a smaller increase of labor taxes on firms with a smaller decrease of consumption taxes respectively relative to the thresholds given by expressions (38) and (39), and keep labor tax on the middle age τ_t^l unchanged. This policy prescription is again similar to the one previously described.

Similarly to Correia et al. [1] a liquidity trap is here resolved with an inflation boost, although based on an opposite prescription in this credit constrained economy.

5 Final remarks

This paper shows that a redistributive tax policy may effectively counteract a liquidity trap with no need to increase public spending or debt, by taking advantage of the liquidity constraints in the economy. In fact, if consumption taxes decrease then consumption increases for liquidity constrained households¹⁵, expanding aggregate demand, and increasing inflation. To keep the budget balanced income taxes are raised for credit unconstrained households, causing a contraction of aggregate savings, and an increase of real interest rates. This may prevent the full-employment real rate from falling due to a zero bound shock, keeping it at an attainable level, sustaining employment level, and preventing or counteracting a recession.

This tax prescription to counteract a liquidity trap with no need to increase public spending and debt, when liquidity is constrained, is curiously opposite to the one proposed by Correia et al. [1] when liquidity is unconstrained. Their *Unconventional Fiscal Policy at the Zero Bound* is based on generating inflation in consumer

¹⁵For example, household who may be subject to binding borrowing limits, or who are receiving the minimum wage or pension income, or who are dissaving to consume.

prices, the ones that matter for intertemporal decisions, with an increasing path of consumption taxes during the temporary¹⁶ slump. Producer price inflation is in turn kept at zero through a decreasing path of labor income taxes. Their tax prescription could worsen a recession when liquidity constraints are present. In fact, increasing consumption taxes would reduce consumption of the liquidity constrained, lowering aggregate demand further away from its full-employment level. Additionally lower labor taxes would expand savings. In an economy where some agents are credit constrained this would further reduce the natural rate of interest, eventually away from an implementable level, which would worsen a zero bound recession.

The redistributive tax policy is effective at counteracting a liquidity trap in open economies if sales tax reduction falls on non-tradable goods and services, and increasing labor taxes on firms falls on non-tradable sectors.

To conclude, choosing an appropriate fiscal prescription to counteract a liquidity trap with no need to increase public spending should take into account the level of liquidity constraints in the economy.

¹⁶by construction.

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A Capital Income Tax

Introducing capital, and a capital income tax in the model, does not qualitatively change the fiscal policy options derived so far to counteract persistent recessions. By having an impact similar to the consumption tax in expanding aggregate demand, reducing the tax on capital can be an effective alternative to a reduction of consumption taxes when further expanding consumption is not a desirable policy option. The model with capital is derived in appendix.

We introduce distortionary taxes including the tax on capital income in the budget constraints of the middle age and old, given by:

$$(1 + \tau_{t+1}^c)C_{t+1}^m = z_{t+1} + w_{t+1}L_{t+1}(1 - \tau_{t+1}^l) + K_{t+1}[r_{t+1}^k(1 - \tau_{t+1}^k) - 1] - (1 + r_t)B_t^y + B_{t+1}^m \quad (40)$$

$$(1 + \tau_{t+2}^c)C_{t+2}^o = -(1 + r_{t+1})B_{t+1}^m + K_{t+1}(1 - \delta) \quad (41)$$

and the labor tax on firms is still considered in the firm problem, now given by:

$$Z_t = \max_{L_t, K_t} \{P_t Y_t - W_t L_t(1 + \tau_t^w) - P_t r_t^k K_t\} \text{ s.t. } Y_t = A_t L_t^\alpha K_t^{1-\alpha} \quad (42)$$

where, $w_t = \frac{W_t}{P_t} = \frac{\alpha L_t^{\alpha-1}}{1 + \tau_t^w} = \frac{\alpha}{1 + \tau_t^w} \frac{Y_t}{L_t}$ and $r_t^k = (1 - \alpha)A_t L_t^\alpha K_t^{-\alpha} = (1 - \alpha) \frac{Y_t}{K_t}$. From the return on capital expression we can directly observe that a reduction of the tax on capital income reduces the cost of capital:

$$r_t^k = \frac{1}{1 - \tau_t^k} \left(1 - \frac{1 - \delta}{1 + r_t} \right) \quad (43)$$

Aggregate demand expands when if the tax on capital income decreases. This can be directly observed from the following expression of aggregate demand in real terms:

$$Y_t^d = \frac{1}{1 - \alpha \tau_t^{lw} - (1 - \alpha)B_t^l} \left[\frac{1 + \beta}{\beta} \frac{(1 + g_t)D_t}{1 + r_t} - D_{t-1} \right] \quad (44)$$

Where $B_t^l = \frac{1}{r_t^k} \frac{1 + \beta}{\beta} \frac{1 - \delta}{r_t + \delta} = (1 - \tau_t^k) \frac{1 + \beta}{\beta} \frac{1 - \delta}{r_t + \delta}$.

Regarding aggregate supply, its expressions is equal to the one derived previously and given by expression (??). But now full employment output is given by:

$$Y_t^f = A_t \bar{L}^\alpha K_t^{1-\alpha} = \bar{L} A_t^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{r_t^k} \right)^{\frac{1-\alpha}{\alpha}} = \bar{L} A_t^{\frac{1-\alpha}{\alpha}} \left[\frac{(1-\alpha)(1-\tau_t^k)}{1 - \frac{1-\delta}{1+r_t}} \right]^{\frac{1-\alpha}{\alpha}} \quad (45)$$

The difference lies on the aggregate supply expression for positive inflation levels which is not constant, and expands when τ^k decreases, leading also to an aggregate supply expansion when inflation is negative. Although a reduction of the tax on capital income has an expanding impact on both aggregate supply and demand, the impact on demand prevails. The resulting impact on inflation, employment and the natural rate of interest are qualitatively similar to the ones derived for the consumption tax, being an available adequate alternative to this instrument in counteracting a persistent recession.